On the Science of Consciousness in Ancient India

Subhash C. Kak
Department of Electrical and Computer Engineering
Louisiana State University
Baton Rouge, LA 70803-5901

Indian Journal of History of Science, vol. 32, 1997, 105-120

Abstract

That cognitive science was the queen of Indian sciences is well known, but the developmental stages by which its various branches arose are not well understood. Within the Indian tradition it is customary to trace fundamental ideas to the Vedic literature. This paper presents a summary of the Vedic theory of consciousness, the most broad expression of Indian cognitive science, within a framework of contemporary scientific concepts. Certain issues related to a historical development of these ideas are also examined.

1 Introduction

Consciousness is described as the ultimate mystery in ancient Indian texts and its study is lauded as the highest science. But until recently, the question of consciousness was considered to lie outside of the scope of science[1] and, consequently, the references in the Indian texts to consciousness have not been examined for their significance to the history of science in India. But before a chronology of the ideas related to consciousness can be developed it is essential to understand their scientific significance and separate what can be correlated with the emerging insights of cognitive science from the more speculative philosophical and religious thought.

Scientific attitudes towards consciousness have changed due to the recent advances in neurophysiology and because modern physics and computer science are confronted with the question of the nature of the observer. In many ways, the study of consciousness is centre-stage in the discussions of modern science[2]. On the other hand, a considerable part of Indian thought is devoted to the question of consciousness. Although a part of this tradition deals with philosophical issues, there are other aspects, as in yoga and tantra, that deal with structural aspects. Books such as Yogavāsiṣṭha and Tripurārahasya claim to describe the nature of consciousness. The same is generally true of various works on yoga, the upaniṣads, and even the earlier Vedic texts. The task for the historian of science is to sketch an evolution of the ideas related to consciousness and see how this sketch fits with the development of other scientific ideas. Since Indian works related to consciousness have not yet been systematically examined, it is perhaps premature to write such a history.

Note that there are intriguing parallels between the insights of the early Vedic theory of consciousness and those of quantum mechanics and neuroscience. In the Vedic theory, which dates back[3]to at least 2000 BC, one views awareness in terms of the reflection that the hardware of the brain provides to an underlying illuminating or awareness principle called the *self*. This approach allows one to separate questions of the tools of awareness, such as vision, hearing and the mind, from the person who obtains this awareness. The person is the conscious self, who is taken to be a reservoir of infinite potential. But the actual capabilities of the animal are determined by the neural hardware of its brain. This hardware may be compared to a mirror. The hardware of the human brain represents the clearest structure to focus the self, which is why humans are able to perform in ways that other animals cannot. Within the framework of this theory humans and other animals are persons and their apparent behavioral distinctions arise from the increased cloudedness of the neural hardware of the lower animals. Self-awareness is an emergent phenomenon which is grounded on the self *and* the associations stored in the brain.

From a modern scientific viewpoint, living systems are dynamic structures, that are defined in terms of their interaction with their environment. Their behavior is taken to reflect their past history in terms of instincts. Living systems can also be defined recursively in terms of living sub-systems. Thus, for ants, one may consider their society, an ant colony, as a living su-

perorganism; in turn, the ant's sub-systems are also living. Such a recursive definition appears basic to all life. Machines, on the other hand, are based on networking of elements so as to instrument a well-defined computing procedure and they lack a recursive self definition.

The reality of consciousness is evident not only from the fact that responses are different in sleepwalking and awake states but from the considerable experimentation with split-brain patients.[4] The experiments of Kornhuber[5] indicate that it takes about eight-tenths of a second for the readiness potential to build up in the brain before voluntary action begins. According to Libet[6] the mind extrapolates back in time by about half a second or so the occurrence of certain events. So consciousness is not an epiphenomenon. As it possesses a unity, it should be described by a quantum mechanical wavefunction.

Eugene Wigner[7] argued that the laws of quantum mechanics may not apply to conscious agents. In a variant of the setting of the Schrödinger cat experiment, he visualized two conscious agents, one inside the box and another outside. If the inside agent makes an observation that leads to the collapse of the wavefunction, then how is the linear superposition of the states for the outside observer to be viewed? Wigner argued that in such a case, with a conscious observer as part of the system, linear superposition must not apply. This result, now called the Wigner's friend paradox, and others have led many quantum theorists to argue that basic advances in physics would eventually require one to include consciousness in the scientific framework.

The Vedic system, which was an earlier attempt to unify knowledge, was confronted by similar paradoxes. It is well known that Schrödinger's development of quantum mechanics was inspired, in part, by Vedānta[8], the full-blossomed Vedic system. His debt to the Vedic views is expressed in an essay he wrote in 1925 *before* he created his quantum theory:

> This life of yours which you are living is not merely a piece of this entire existence, but is in a certain sense the "whole"; only this whole is not so constituted that it can be surveyed in one single glance. This, as we know, is what the Brahmins express in that sacred, mystic formula which is yet really so simple and so clear: *tat tvam asi*, this is you. Or, again, in such words as "I am in the east and the west. I am above and below, *I am this entire world*[9].

Schrödinger used Vedic ideas also in his immensely influential book *What is Life?*[10] that played a significant role in the development of modern biology. According to his biographer Walter Moore, there is a clear continuity between Schrödinger's understanding of Vedanta and his research:

> The unity and continuity of Vedanta are reflected in the unity and continuity of wave mechanics. In 1925, the world view of physics was a model of a great machine composed of separable interacting material particles. During the next few years, Schrödinger and Heisenberg and their followers created a universe based on superimposed inseparable waves of probability amplitudes. This new view would be entirely consistent with the Vedantic concept of All in One[11].

In view of this connection between the Vedic system and quantum mechanics and the fact that quantum mechanical models of consciousness are being attempted, it is important to see how the Vedic philosophers developed their classificatory models of consciousness. A summary of one classificatory model is the main focus of the paper. The question of the history of ideas related to the notion of consciousness in ancient India will also be touched upon briefly in this paper.

2 Psychology, complementarity

2.1 Self, biology, psychology

Neural network models have been used by cognitive scientists to model behaviour. The limitations of neural models have been highlighted by Sacks[12] and others who point out that these models do not take into account the notion of self.

The limitations of current theories of psychology were well summarized by the distinguished Canadian psychologist Melzack[13]:

> The field of psychology is in a state of crisis. We are no closer now to understanding the most fundamental problems of psychology than we were when psychology became a science a hundred years ago. Each of us is aware of being a unique "self", different from other people and the world around us. But the nature of

> the "self", which is central to all psychology, has no physiological basis in any contemporary theory and continues to elude us. The concept of "mind" is as perplexing as ever... There is a profusion of little theories–theories of vision, pain, behaviour-modification, and so forth–but no broad unifying concepts... Cognitive psychology has recently been proclaimed as the revolutionary concept which will lead us away from the sterility of behaviourism. The freedom to talk about major psychological topics such as awareness and perceptual illusions does, indeed, represent a great advance over behaviourism. But on closer examination, cognitive psychology turns out to be little more than the psychology of William James published in 1890; some neuroscience and computer technology have been stirred in with the old psychological ingredients, but there have been no important conceptual advances... We are adrift, without the anchor of neuropsychological theory, in a sea of facts–and practically drowning in them. We desperately need new concepts, new approaches.

Cognitive abilities arise from a continuing reflection on the perceived world and this question of reflection is central to the brain-mind problem, the measurement problem of physics, and the problem of determinism and free-will[14]. A dualist hypothesis[15]to explain brain-mind interaction or the process of reflection meets with the criticism that this violates the conservation laws of physics. On the other hand a brain-mind identity hypothesis, with a mechanistic or electronic representation of the brain processes, does not explain how self-awareness could arise. At the level of ordinary perception there exists a duality and complementarity between an autonomous (and reflexive) brain and a mind with intentionality.

2.2 Complementarity

The notion of self seems to hinge on an indivisibility akin to that found in quantum mechanics. The wave-particle duality encountered in quantum phenomena led Neils Bohr in 1927 to introduce the notion of complementarity. Complementarity is the principle that description of reality in any of the mutually contradictory pictures is incomplete; but between them such pictures form a complete, complementary description. This principle also

presupposes that experiments can be unambiguously described only in classical terms. Considering the question of logical foundations of biology Bohr concluded that life (and also cognitive) processes are likewise subject to complementarity. The complementarity exhibited by life may be expressed most fundamentally between structure and behavior.

> The recognition of the limitation of mechanical concepts in atomic physics would rather seem suited to conciliate the apparently contrasting viewpoints of physiology and psychology. Indeed, the necessity of considering the interaction between the measuring instruments and the object under investigation in atomic mechanics exhibits a close analogy to the peculiar difficulties in psychological analysis arising from the fact that the mental content is invariably altered when the attention is concentrated on any special feature of it[16].

Bohr suggested an interesting analogy between neural (thought) and quantum processes. The instantaneous state of a thought may be compared with the position of a particle, whereas the direction of change of that thought may be compared with the particle's momentum. This is described by Bohm as follows[17]:

> Part of the significance of each element of a thought process appears to originate in its indivisible and incompletely controllable connections with other elements. Similarly, some of the characteristic properties of a quantum system (for instance, wave or particle nature) depend on indivisible and incompletely controllable quantum connections with surrounding objects. Thus, thought processes and quantum systems are analogous in that they cannot be analyzed too much in terms of distinct elements, because the *intrinsic* nature of each element is not a property existing separately from and independently of other elements but is, instead, a property that arises partially from its relation with other elements.

There is also a similarity between the thought process and the classical limit of the quantum theory. The logical process corresponds to the most general type of thought process as the classical limit corresponds to the most general

quantum process. In the logical process, we deal with classifications. These classifications are conceived as being completely separate but related by the rules of logic, which may be regarded as the analogue of the causal laws of classical physics. In any thought process, the component ideas are not separate but flow steadily and indivisibly. An attempt to analyze them into separate parts destroys or changes their meanings. Yet there are certain types of concepts, among which are those involving the classification of objects, in which we can, without producing any essential changes, neglect the indivisible and incompletely controllable connection with other ideas.

Complementarity is required at different levels of description. But just as one might use a probabilistic interpretation instead of complementarity for atomic descriptions, a probabilistic description may also be used for cognitive behavior. However, such a probabilistic behavior is inadequate to describe the behavior of individual agents, just as notions of probability break down for individual objects.

As an epistemological principle complementarity has been criticized for not providing a unifying picture. But from an operational point of view complementarity, by considering all kinds of responses, becomes a very useful approach. When analyzed in terms of local interactions the framework of quantum mechanics suffers from other paradoxical characteristics. This shows up in non-local correlations that appear in the manner of action at a distance[18].

3 The Vedic System of Knowledge

The Vedic system of knowledge appears already to be in place by the time of the Ṛgveda, conservatively dated to the late third or early second millennia BC[19]. The Ṛgveda and the other Vedic books do not present a logical resolution of the paradox of consciousness but assert that knowledge is of two types: it is superficially dual but at a deeper level it has a unity. The Vedic theory implies a complementarity by insisting that the material and the conscious are aspects of the same transcendent reality. The modern scientific tradition is like the Vedic tradition since it it acknowledges contradictory or dual descriptions but seeks unifying explanations.

The Vedic approach to knowledge was based on the assumption that there exist equivalences of diverse kinds between the outer and the inner worlds.

This prompted a deep examination of the human mind. In the description of physical reality the Vedic scholars noted several paradoxes[20]. If matter is divisible, each atom must be point-like because otherwise it would be further divisible. But how do point-like atoms lead to gross matter with size? Space is neither continuous nor discontinuous, for if it were continuous its points would be non-enumerable, but if it is discontinuous then how do objects move across the discontinuity? A popular way to express these difficulties was to talk about the riddle of being and becoming. The basic question here is how does an entity change its form and become another?

The philosophical systems that arose in India early on were meant to help one to find clues to the nature of consciousness. It was recognized that a complementarity existed between different approaches to reality, presenting contradictory perspectives. That is why philosophies of logic (nyāya) and physics (vaiśeṣika), cosmology and self (sāṅkhya) and psychology (yoga), and language (mimāṃsa) and reality (vedānta) were grouped together in pairs. The system of Sāṅkhya considered a representation of matter and mind in different enumerative categories. The actual analysis of the physical world was continued outside of the cognitive tradition of Sāṅkhya in the sister system of Vaiśeṣika, that deals with further characteristics of the gross elements. The atomic doctrine of Vaiśeṣika can be seen to be an extension of the method of counting in terms of categories and relationships. The reality in itself was taken to be complex, continuous and beyond logical explanation. However, its representation in terms of the gross elements like space, mass (earth), energy (fire) and so on that are cognitively apprehendable, can be analyzed in discrete categories leading to atomicity. The cosmology of Sāṅkhya is really a reflection of the development of the mind, represented in cognitive categories.

The Greek philosophers also spoke of paradoxes inherent in descriptions. For example, we have Zeno's famed paradoxes on motion. But the Greek tradition does not appear to have dealt with the problem of consciousness.

4 The Vedic Model of the Mind

One Vedic model of the mind is expressed by the famous metaphor of the chariot in Kaṭha Upaniṣad and the Bhagavad Gītā. A person is compared to a chariot that is pulled in different directions by the horses yoked to

it; the horses represent the senses. The mind is the driver who holds the reins to these horses; but next to the mind sits the true observer, the self, who represents a universal unity. Without this self no coherent behaviour is possible.

4.1 The Five Levels

In the Taittirīya Upaniṣad an individual is represented in terms of five different sheaths or levels that enclose the individual's self. These levels, shown in an ascending order, are:

- The physical body (annamaya kośa)
- Energy sheath (prāṇamaya kośa)
- Mental sheath (manomaya kośa)
- Intellect sheath (vijñānamaya kośa)
- Emotion sheath (ānandamaya kośa)

Here I have translated ānanda as emotion rather than the customary bliss, since emotion is the closest cognitive category to the Sanskrit term. These sheaths are defined at increasingly finer levels. At the highest level, above the emotion sheath, is the self. It is significant that emotion is placed higher than the intellect. This is a recognition of the fact that eventually meaning is communicated by associations which are influenced by the emotional state.

The energy that underlies physical and mental processes is called prāṇa. One may look at an individual in three different levels. At the lowest level is the physical body, at the next higher level is the energy systems at work, and at the next higher level are the thoughts. Since the three levels are interrelated, the energy situation may be changed by inputs either at the physical level or at the mental level. When the energy state is agitated and restless, it is characterized by rajas; when it is dull and lethargic, it is characterized by tamas. The state of equilibrium and balance is termed sattva.

Prāṇa, or energy, is described as the currency, or the medium of exchange, of the psychophysiological system. The levels 3, 4, and 5 are often lumped together and called the mind.

The key notion is that each higher level represents characteristics that are emergent on the ground of the previous level. In this theory mind is an emergent entity, but this emergence requires the presence of the self.

4.2 The Structure of the Mind

Now we consider the structural characteristics of the mind as given by the Sāṅkhya system. The mind is viewed as consisting of five components: manas, ahaṃkāra, citta, buddhi, and ātman.

Manas is the lower mind which collects sense impressions. Its perceptions shift from moment to moment. This sensory-motor mind obtains its inputs from the senses of hearing, touch, sight, taste, and smell. Each of these senses may be taken to be governed by a separate agent.

Ahaṃkāra is the sense of I-ness that associates some perceptions to a subjective and personal experience.

Once sensory impressions have been related to I-ness by ahaṃkāra, their evaluation and resulting decisions are arrived at by buddhi, the intellect. Manas, ahaṃkāra, and buddhi are collectively called the internal instruments of the mind.

Next we come to citta, which is the memory bank of the mind. These memories constitute the foundation on which the rest of the mind operates. But citta is not merely a passive instrument. The organization of the new impressions throws up instinctual or primitive urges that creates different emotional states.

This mental complex surrounds the innermost aspect of consciousness which is called ātman. It is also called the self, brahman, or jīva. Ātman is considered to be beyond a finite enumeration of categories.

4.3 Hierarchical Levels Within the Brain

Since the state of mind is mediated by the pranic energy, it becomes useful to determine how this is related to the focus on the various parts of the body. In the tantras seven, eight, or nine points of primary focus which are called cakras are described. It has been argued by some that the beginnings of this system go right back to the Vedic times as in Atharvaveda 10.2.31-2 which describes the body as being eight-wheeled and nine-doored (aṣṭācakrā navadvārā devānāṃ pūryodhyā). Their positions appear to be areas in the

brain which map to different points on the spinal cord. The lowest one is located at the bottom of the vertebral column (mūlādhāra cakra). The next cakra is a few inches higher at the reproductive organs (svādhiṣṭhāna cakra). The third cakra (maṇipūra cakra) is at the solar plexus. The heart region is the anāhata cakra. The throat has the fifth cakra called the viśuddhi cakra. Between the eyebrows is the ājñā cakra. At the top of the head is the sahasrāra cakra.[21]

It may be assumed that the stimulation of these cakras in a proper way leads to the development of certain neural structures that allow the I-ness to experience the self. In other words, the cakras are points of basic focus inside the brain that lead to the explication of the cognitive process.

4.4 Further Universal Categories

If the categories of the mind are taken to arise from pattern recognition of shadow mental images, then how are these categories associated with a single 'agent', and how does the mind bootstrap these shadow categories to find the nature of reality?

These questions were considered by later scholars who further developed the earlier Vedic ideas. This development occurred within the frameworks of Vaiṣṇavism as well as Śaivism. Here we speak of only one specific development that took place in Kashmir and has come to be known as Kashmir Śaivism[22]. The beginning of this specific tradition is seen in the Śiva Sūtras of Vasugupta (c. 800 AD). The Śiva Sūtras have aphorisms such as:

> 1.1 caitanyamātmā (Consciousness is the self)
>
> 2.5 vidyāsamutthāne svābhāvike khecarī śivāvasthā (The knowledge of one's innate nature leads to Śiva's state: it is like wandering in the sky of consciousness)

Śiva is the name for the absolute or transcendental consciousness. Ordinary consciousness is bound by cognitive categories related to conditioned behavior. By exploring the true springwells of ordinary consciousness one comes to recognize its universal (Śiva). This brings the further recognition that one is not a slave (paśu) of creation but its master (pati).

According to Sāṅkhya, reality may be represented in terms of twenty five categories. These categories form the substratum of the classification in Śaivism. These categories are:

- (i) five elements of materiality, represented by earth, water, fire, air, ether;
- (ii) five subtle elements , represented by smell, taste, form, touch, sound;
- (iii) five organs of action, represented by reproduction, excretion, locomotion, grasping, speech;
- (iv) five organs of cognition, related to smell, taste, vision, touch, hearing;
- (v) three internal organs, being mind, ego, and intellect; and inherent nature (prakṛti), and
- consciousness (puruṣa).

These categories define the structure of the physical world and of agents and their minds. But this classification is not rich enough to describe the processes of consciousness as it is mentioned as a single category.

Śaivism enumerates further characteristics of consciousness:

- (vii) sheaths or limitations of consciousness, being time (kāla), space (niyati), selectivity (rāga), awareness (vidyā), creativity (kalā), self-forgetting (māyā), and
- (viii) five principles of the universal experience, which are correlation in the universal experience (sadvidyā, śuddhavidyā), identification of the universal (īśvara), the principle of being (sādākhya), the principle of negation and potentialization (śakti), and pure awareness by itself (śiva)

The first twenty five categories relate to an everyday classification of reality where the initial five characteristics relate to the physical inanimate world, and the next eighteen define the characteristics of the conscious organism. The inherent nature of the individual is called prakṛti while puruṣa represents self.

The next eleven categories characterize different aspects of consciousness which is to be understood in a sense different to that of mental capacities (categories 21,22,23). One of these mental capacities is akin to artificial

intelligence of current computer science, which is geared to finding patterns and deciding between hypotheses. On the other hand categories 26 through 36 deal with interrelationships in space and time between these patterns and deeper levels of comprehension and awareness.

Any focus of consciousness must first be circumscribed by coordinates of time and space. Next, it is essential to select a process (out of the many defined) for attention (category 28). The aspect of consciousness that makes one have a feeling of inclusiveness with this process, followed later by a sense of alienation is called māyā (category 31). Thus māyā permits one, by a process of identification and detachment, to obtain limited knowledge (category 29) and to be creative (category 30).

4.4.1 Universal Experience

How does consciousness ebb and flow between an identity of self and an identity with the processes of the universe? According to Śaivism, a higher category (number 32) permits comprehension of oneness and separation with equal clarity. On the other hand category 33 allows a visualization of the ideal universe. Category 33 allows one to move beyond mere comprehension into a will to act. The final two categories deal with the potential energy that leads to continuing transformation (35) and pure consciousness by itself (36). Pure awareness is not to be understood as similar to everyday awareness of humans but rather as the underlying schema that the laws of nature express. The laws themselves define the śakti tattva.

The cognitive categories of Śaivism are of relevance in computer science. At present only a subset of these categories can be dealt with by the most versatile computing machines. Current research is focused on the lower categories such as endowing machines with action capacities (as in robotics) and powers of sense perception (as in vision). At the higher levels, machines can be endowed with some capacity for judgment that typically involves computation of suitably framed cost functions, or finding patterns, of choosing between hypotheses, but the capacities of concretization and especially self-awareness seem to be completely out of the realm of present day computing science.

4.5 A Theory of Speech and Cognition

Ṛgveda 1.164.45 describes that speech and its concomitant cognition is of four kinds. The names of these kinds of speech are described by Bhartṛhari (c 450 AD) in his Vākyapadīya to be vaikharī, madhyamā, paśyantī, and parā[23]. Vaikharī represents gross sound; madhyamā is the level of mental images; paśyantī represents that gestalt or undifferentiated whole that sounds emerge from in the process of speaking and into which they merge in the process of hearing; parā is the unmanifest sound that resides in one's self or universal consciousness.

Bhartṛhari argues that reality (sampratisattā) when seen through the window of language reduces to a formal reality (aupacārikī sattā). Language can only deal upto the level of paśyantī, the gestalts underlying mental constructs, and it remains limited because parā speech lies beyond it.

Bhartṛhari calls the word or sentence considered an an indivisible meaning-unit as the sphoṭa. He bases this concept on the Vedic theory that speech (vāk) is a manifestation of the primordial reality. The word-sphoṭa is thus contrasted from word-sound. Meaning is obtained at a deep level based on the sequence of sounds.

The discovery of a very large number of phonetic symmetries in the first hymn of the Ṛgveda that cannot be conceived to have been deliberately introduced gives support to the thesis that language captures only some of the symmetries that nature's intelligence can express. Raster summarizes this discovery thus[24]:

> In our search for phonetic symmetries in the first sūkta of the Ṛgveda, we examined the occurrence frequencies of more than 50 sound classes. Of these more than 40 sound classes were found with occurrence frequencies which are integral multiples of 8 and more than 20 sound classes with occurrence frequencies which are even integral multiples of 24... Moreover, in many cases, the occurrence frequencies of phonetically related sound classes form simple integral ratios, for example, the ratio of 2:1 between the frequencies of voiced and voiceless consonants and the ratio of 1:2 between the frequencies of long and short vowels. Thus, fundamental oppositions of the phonological system are reflected in the quantitative distribution of sounds in the text... The order which has been found underlying the phonological structure of the

> text is a hidden order. It cannot be perceived consciously while reading or listening to the text... Although the order found in the distribution of the sounds in the text is unfolded sequentially in time, it is in itself not a linear, but a global phenomenon...[and] it is multidimensional. [Page 38]

Bhartṛhari's theory speaks of a reality richer than the expressive power of any language. Like the observables of quantum theory, language picks only processes associated with its expressions.

The Vedic theory of consciousness speaks of a process of evolution. In this evolution the higher animals have a greater capacity to grasp the nature of the universe. The urge to evolve into higher forms is taken to be inherent in nature. A system of an evolution from inanimate to progressively higher life is clearly spelt out in the system of Sāṅkhya. At the mythological level this is represented by an ascent of Viṣṇu through the forms of fish, tortoise, boar, man-lion, the dwarf into man.

5 Concluding Remarks

The classificatory systems developed in the Indian tradition do not address the paradoxes of consciousness. Rather, categories are defined, such as that of universal experience, that can be seen to be explain the "complementary" nature of human experience. These categories clearly assign central role to selectivity, or context, and change. The Vedic system takes the mind to be emergent on the ground of the neural hardware of the brain, but this emergence is contingent on the principle of the self. In the earliest literature, the gods represent various cognitive centres. Tantric texts use esoteric diagrams or yantras for their representation.[25]There are other systems which are based on basic sounds of the alphabet related to fundamental aspects of the mind.[26]Such ideas have been, by tradition, consigned to philosophy or yoga and tantra. But it is possible, indeed likely, that there is much more than speculative thought in these models.

The ancient tradition of consciousness study in India, long limited to philosophical studies, remains an unexplored frontier in the history of science. This paper is just an introduction to the problem. Further advances in a scientific understanding of consciousness will lead to a better appreciation of the Indian literature on the subject. One hopes that a comprehensive

chronology of the various developments in the structural models of consciousness will be eventually produced.

Notes

1. Crick, F. and Koch, F., The problem of consciousness. *Scientific American*, 267(9), 153-159, 1992;
   Kak, S., Reflections in clouded mirrors: selfhood in animals and machines. *Symposium on Aliens, Apes, and Artificial Intelligence.* Southern Humanities Council Annual Conference, Huntsville, AL, February 1993;
   Goswami, A., *The Self-Aware Universe.* New York: G.P. Putnam's Sons, 1993;
   Horgan, J., Can science explain consciousness? *Scientific American* 269(7), 88-94, 1994.

2. Edelman, G., *The Remembered Present: A Biological Theory of Consciousness.* New York: Basic Books, 1989;
   Penrose, R., *Shadows of the Mind.* Oxford: Oxford University Press, 1994;
   Scott, A.C., *Stairway to the Mind: The Controversial New Science of Consciousness.* New York: Springer-Verlag, 1995;
   Kak, S., Quantum neural computing. *Advances in Imaging and Electron Physics* 94, 259-313, 1995;
   Kak, S., The three languages of the brain: quantum, reorganizational, and associative. *4th Appalachian Conf. on Behavioral Neurodynamics.* Radford, VA, Sept 1995;
   Kak, S., Information, physics, and computation. *Foundations of Physics* 26, 127-137, 1996;
   Kak, S., Why machines cannot be conscious. Presented at *Towards a Science of Consciousness 1996*, Tucson, April 1996;
   Hameroff, S. and Penrose, R., Conscious events as orchestrated space-time selections. *Journal of Consciousness Studies* 3, 36-53, 1996.

3. Kak, S.C., *The Astronomical Code of the Ṛgveda.* New Delhi: Aditya, 1994;

Feuerstein, G., Kak, S., Frawley, D., *In Search of the Cradle of Civilization.* Wheaton: Quest Books, 1995.

4. Trevarthen, C. (Ed.), *Brain Circuits and Functions of the Mind: Essays in Honor of Roger W. Sperry.* Cambridge: Cambridge University Press, 1990.

5. Kornhuber, H.H., Cerebral cortex, cerebellum, and basal ganglia: An introduction to their motor function. In W. Schmitt (ed.), *The Neurosciences: Third Study Program.* Cambridge: MIT Press, 1974.

6. Libet, B., Electrical stimulation of cortex in human subjects, and conscious sensory aspects. In A. Iggo (ed.), *Handbook of sensory physiology: Vol. II. Somatosensory System.* New York: Springer-Verlag, 1973.

7. Wigner, E., *Symmetries and Reflections.* Bloomington: Indiana University Press, 1967.

8. Schrödinger, E., *Meine Weltansicht.* Wien: Paul Zsolnay, 1961.

9. Moore, W., *Schrödinger: Life And Thought.* Cambridge University Press, 1989, pages 170-3.

10. Schrödinger, E., *What Is Life?.* New York: Macmillan, 1965.

11. Moore op. cit. page 173.

12. Sacks, O., *Awakenings, A Leg To Stand On, The Man Who Mistook His Wife For A Hat.* New York: Book of the Month Club, 1990.

13. Melzack, R., Phantom limbs, the self and the brain. *Canadian Psychology*, 30, 1-16, 1989, pages 1-2.

14. Kak, S.C., *The Nature of Physical Reality.* New York: Peter Lang, 1986.
    Penrose, R., *The Emperor's New Mind: Concerning Computers, Minds, And The Laws Of Physics.* Oxford University Press, 1989.

15. Eccles, J.C., Do mental events cause neural events analogously to the probability fields of quantum mechanics? *Proc. Royal Society London*, B 227, 411-428, 1986.

16. Bohr, N., *Atomic Physics and Human Knowledge.* New York: Science Editions, 1961.

17. Bohm, D., *Quantum Theory.* New York: Prentice-Hall, 1951.

18. Bell, J.S., *Speakable and Unspeakable in Quantum Mechanics.* Cambridge: Cambridge University Press. 1987.

19. Feuerstein et al, op cit.

20. Kak, The Nature of Physical Reality, op. cit.

21. Feuerstein, G., *Yoga.* Los Angeles: Jeremy P. Tarcher, 1989.

22. Abhinavagupta, R., *A Trident of Wisdom.* Albany: State University of New York Press, 1989;
Singh, Jaideva, *Śiva Sūtras.* Delhi: Motilal Banarsidass, 1979;
Dyczkowski, M.S.G., *The Doctrine of Vibration.* Albany: SUNY Press, 1987.

23. Abhyankar, K.V. and Limaye, V.P., *Vākyapadīya of Bhartṛhari.* Poona: University of Poona, 1965.
Coward, H.G., *Bhartṛhari.* Boston: Twayne Publishers, 1976.

24. Raster, P., *Phonetic Symmetries in the First Hymn of the Rigveda.* Innsbruck, 1992.

25. Woodroffe, J., *The Serpent Power.* Madras: Ganesh and Co., 1981;
Feuerstein, op cit.

26. Abhinavagupta, *Parātrīśikā-Vivaraṇa.* Delhi: Motilal Banarsidass, 1988.